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NOTES ON THE FINER STRUCTURE OF THE NERVOUS SYSTEM OF *CYNTHIA PARTITA* (VERRILL).

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IN the fall of 1897, while working upon the morphology and finer structure of the nervous system of *Cynthia partita* (Verrill), after noting the papers of Von Lenhosseck ('95), Dehler ('95), McClure ('96), and Miss Lewis ('96), I was led to look for the centrosome and sphere in the cells of the central nervous system. I was directly prompted to this investigation by an examination of the plates of Van Beneden and Julin's ('84) early paper on the central nervous system of the Ascidians. In Pl. I, Figs. 2 and 3, these authors represent ganglion cells with excentric invaginated nuclei. Careful study showed the same thing to be true for the ganglion cells of *Cynthia*. I was, however, not immediately successful in staining the centrosome, although later material killed in more favorable reagents showed that a structure homologous with the centrosome and sphere of authors exists in the tunicate ganglion cell. The incomplete notes on fibrillar structure of the nerve trunks are given in view of the recent papers of Apathy ('97) and Bethe ('98). It is hoped in a later paper to give a more complete account of the cell structures and their relation to the neuron.

METHODS.

Several fixing fluids were employed. They were found to be of extremely varying utility as preservatives of the finer structure of the central nervous system. The fluids of Flem-

ming, Hermann, Von Rath, and aqueous or alcoholic solutions of corrosive sublimate gave uniformly favorable results. Specimens were left in Flemming or Hermann from one to two hours, and in corrosive from one-half an hour to six hours, according to the size of the specimen. The shorter periods gave better results. The method of Von Rath was somewhat modified. Specimens were left in his picro-acetic-platinicosmic mixture from one to four hours, washed six hours in methyl alcohol, twenty-four hours in pyroligneous acid, and several days in weak alcohol, before leaving permanently in 95%. Such specimens, passed through xylol or oil of bergamot, imbedded in paraffin, and cut from two to three *micra* thick, gave the most satisfactory results, especially when stained in Heidenhain's iron-haematoxylin. Of the other killing fluids used I found Lang's fluid, Gilson's mixture, and Perenyi gave the most satisfactory results. Chromic, chrom-acetic, chrom-nitric, and corrosive-acetic mixtures shrink the cell-body badly, giving it a vacuolated and fibrillar appearance. Formalin (except in very weak solution), picro-formalin, and picric mixtures were of even less value, destroying the cell elements greatly. As stains, Heidenhain's iron-haematoxylin, with safranin and Biondi-Ehrlich as controls, were employed for general work. The methylen blue-eosin mixture of McClure, and cyanin and erythrosin were used to demonstrate the chromophilous substance in the nerve cell. To demonstrate the structure of the cell prolongations and nerves, thin sections were stained from two to three days in iron-haematoxylin and the stain only partly drawn out. This method gave very favorable results.

STRUCTURE OF THE NERVE CELL.

The cells of the so-called brain differ greatly in size, the largest being situated most peripherally, the smallest most internally. The largest ganglion cells measure 12 *micra* × 16 *micra*, and have a nucleus measuring 4 *micra* × 9 *micra*. Those of medium size, composing the greatest number of cells in the ganglion, average 7 *micra* × 14 *micra*, with nuclei measuring 3 *micra* × 6 *micra*. The smallest cells are 3 to 4 *micra* across,

and 5 to 6 *micra* in length, with nuclei measuring 3 × 4 *micra*. It can be seen that the nucleus is proportionally largest in the smallest cells, therein frequently taking up a large part of the cell-body. The nuclei of the smallest cells are much richer in chromatic matter than are the nuclei of the larger cells, and may easily be confounded with the so-called neuroglia nuclei.

Under the 1-12th oil immersion (Zeiss) the cell appears to have a granulo-fibrillar structure. The granular masses, which stain with haematoxylin and basic analins, are irregular in shape and size, and look in places as if they were made up of smaller granules. They are usually found concentrated in certain regions of the cell, *i.e.*, the extreme periphery, around the nucleus, and sometimes near the center of the cell surrounding the centrosome and sphere. A regular concentric grouping of these granules was scarcely ever found. In general the larger granules are found near the periphery of the cell. They are frequently found forming a reticulum or arranged in rows. It seems probable that these coarse granules are homologous with the chromophilous substance of the vertebrate nerve cell, as well as with that substance in invertebrates (McClure, Pflüge, Lugaro, and others). This is shown by double staining with methylen blue and eosin or erythrosin. Such methods show the cell to be made up of two differently staining elements — a varying number of irregular masses which stain with methylen blue, and a ground substance finely granulo-fibrillar or homogeneous, which takes the red stain. This ground substance seems to be made up of two portions: a semi-fluid (hyloplasm) and a granulo-fibrillar part. In general the blue-staining substance may be said to be restricted to the more peripheral parts of the cell. The masses vary much in size, small granules as well as large masses being seen; the former existing nearer the center of the cell than the latter. In cells containing an excentric invaginated nucleus the area opposite the inpushing of the nuclear membrane is seen to be made up of very fine granules which stain red. In such cells the chromophilous masses were found disposed in the peripheral portion of the cell, around the nucleus.

Besides the granules first described, small groups of refractive bodies — probably pigment granules — are found in some of the cells. Vacuolated spaces are frequent, but are so much increased in size by poor preservation that I am inclined to believe them artifacts. Such spaces may be filled with the hyloplasm of Nansen, Montgomery, and others.

A fibrillar or reticular structure for the nerve cell could not be absolutely proved, although the fibers from the cell process can be followed for some distance into the cell-body. The frequent arrangement of the granular portion of the cell into a sort of network suggests a reticular framework of fibers as indicated by Cajal and Van Gehuchten in the vertebrate nerve cell, or Pflüge in invertebrates.

The nerve cell is surrounded by a thin membrane and in the large ganglion is surrounded by a capsule of fine fibers (neuroglia of authors, or connective-tissue sheath). This capsule can best be seen in cells that are somewhat shrunken.

The nucleus is irregular in contour and appears circular, ovoid, kidney-shaped, or, in extreme cases, cup-shaped. Rarely the invagination has appeared to cut the nucleus into two distinct parts. Never has the nucleus been found to occupy a central position in the cell; it is always excentric, and frequently situated in an outpocketing of the cell. In unipolar cells it is usually found at the opposite end from the cell process; but in many cases it is forced by the action of the centrosome close to the axis-cylinder end of the cell (see Fig. 1).

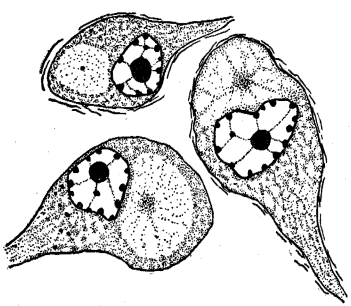

FIG. 1. — Ganglion cells. *Cynthia.* Centrosome and sphere; nucleus at axis-cylinder end of cell. Von Rath. Iron-haematoxylin. Camera drawing. $\frac{1}{12}$ × oc. 6 (Zeiss).

The nuclear membrane is very prominent and stains deeply with haematoxylin and basic analins. The nuclear process of Schultze ('79), Rhode ('96) was found, but it seemed to be an artifact. Binucleated cells were rarely seen.

In large cells the chromatin exists in small particles collected against the nuclear membrane and scattered through the nucleus.

These chromatin granules are held in place, as is the nucleolus, by a finely fibrous achromatic network. In large cells one nucleolus is always present, rarely two. If two are present, one is larger than the other. The nucleolus is frequently observed to be vacuolated. It is often found suspended in the achromatic network of the nucleus, but just as frequently is it found against the nuclear wall. In deeply invaginated nuclei the nucleolus is found against the nuclear wall at the bottom of the invagination, as if the wall had been pushed in until it had reached the nucleus.

In the smaller cells of old specimens as well as the cells of young animals quite a different state exists. The chromatin granules are more evident, being larger, staining deeply, and apparently more numerous than in the large cells. The nucleus, as has been noted, is much larger comparatively than in larger cells. The nucleolus is small. There appears at first sight little difference between these nuclei and those of the so-called neuroglia cells, but a closer investigation shows the latter to be more oval and elongated and to have a less prominent nucleolus than the nerve cell (see Fig. 2). In ganglion cells of young specimens killed a few days after metamorphosis the nucleus is very rich in chromatin, and presents much the same aspect as is shown by the smaller ganglion cells of the adult specimens. The nucleus is proportionately very large, occupying the greater part of the cell-body. In the larger peripherally placed cells of the young

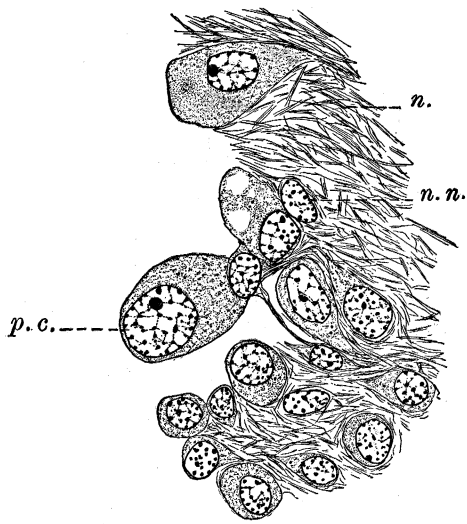

FIG. 2. — Cross-section of periphery of brain of young *Cynthia*, showing absence of connective-tissue sheath. *p.c.*, large peripheral ganglion cells; *n.n.*, neuroglia nuclei; *n.*, neuroglia and nerve fibers. Von Rath. Iron-haematoxylin. $\frac{1}{12}$ × oc. 6 (Zeiss).

specimens the nuclei do not occupy proportionately as much space as in the smaller cells, but still much more space than in cells of corresponding size in older specimens. The nucleus is rarely indented, usually ovoid or nearly spherical, is rich in chromatin, and contains a small nucleolus. In general the condition is more nearly that of the adult ganglion cell (Fig. 2).

THE CELL PROCESS AND NERVE TRUNKS.

The cell process is undoubtedly fibrillar (Schultze, Flemming, Pflüge). A decided entrance cone was frequently observed. In other cases the fibrils appeared to enter the cell-body, and spread out in the cortical part of the cell. This was especially noticeable in material killed in Flemming. In rare cases where only one large fiber or bundle of fibrils seemed to enter the cell, it would be traced for some little distance. This may be similar to the intracellular axis cylinder of Binet ('94).

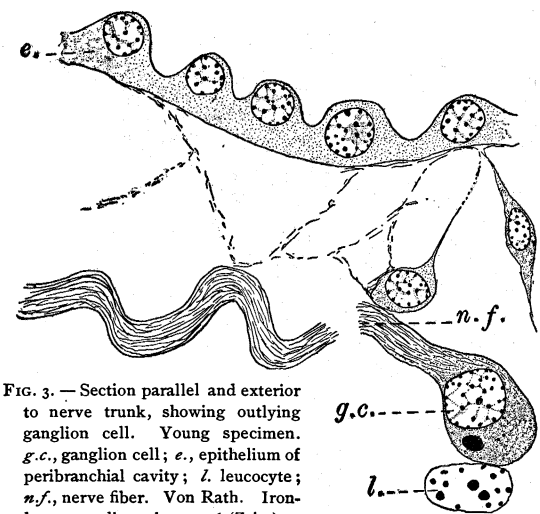

FIG. 3. — Section parallel and exterior to nerve trunk, showing outlying ganglion cell. Young specimen. *g.c.*, ganglion cell; *e.*, epithelium of peribranchial cavity; *l.* leucocyte; *n.f.*, nerve fiber. Von Rath. Iron-haematoxylin. $\frac{1}{12}$ × oc. 6 (Zeiss).

The structure of the cell process in the central system was extremely difficult to make out, but a satisfactory picture could be obtained from young specimens. In such animals the connective-tissue sheath surrounding the central ganglion is not developed, and ganglion cells are frequently found projecting into the loose connective tissue surrounding the ganglion. Indeed they are often near nerve trunks entirely free from the cell mass of the ganglion. Such a cell is shown in Fig. 3. The nerve trunk of which it is a part would be shown in the next section. The fibrillar

structure of the cell process is here plainly seen, as well as the characteristic wavy course of the fibrils. The fibrils do not form an entrance cone, but seem to spread out in the cell-body, especially toward the periphery. In the axis cylinder the fibrils appear to hold an irregular course, and do not run absolutely parallel. These fibrils are separated from each other by a homogeneous substance which does not stain with haematoxylin, and but slightly with eosin or erythrosin. This is the peri-fibrillar substance, probably the hyloplasm of authors. The structure of the sheath is very difficult to make out; it appears to be almost homogeneous or very finely fibrillar, as described by Apathy and Bethe. No myelin substance could be proved. In the nerve trunks the individual processes can rarely be differentiated in longitudinal section, and then only in very small, loosely constructed nerves, such as are found in the dorsal lamina. But in cross-section the structure is much easier to make out. If sections be soaked for twelve hours in the iron-alum solution, and forty-eight hours or more in the haematoxylin solution, then the stain is only slightly drawn out, so that the section looks black, a very good idea of the nerve trunk can be obtained. Fig. 4 shows such a specimen. The nerve trunk is usually free from any connective-tissue envelop and is found lying free in the connective-tissue space (mesenchyme). The sheath of the cell process stains a dull blue or blue black, while the fibrils take a deep black. These fibrils may be united into a little group inside the sheath (when a sheath is present) or scattered indifferently through the perifibrillar substance. Often they are found concentrically arranged just inside the sheath. Sometimes only one or two large fibrils are found.

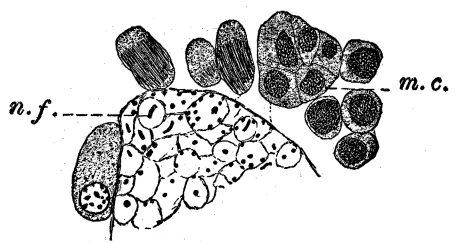

FIG. 4. — Cross-section of nerve trunk in dorsal lamina, showing fibrils and sheaths. Adult specimen. *n.f.*, nerve fibrils; *m.c.*, muscle fibrils in cross-section. Von Rath. Haematoxylin. Camera drawing. $\frac{1}{12}$ × oc. 6 (Zeiss).

It seems probable that one of these stages merges into

another, as Bethe holds, and not that it is an exhibition of anatomical difference between motor and sensory roots, as Apathy seems to believe. In many cases the sheath does not stain, and the fibrils appear to be loose in a non-staining perifibrillar substance. In such conditions they are usually grouped into small bundles of from two or three to a dozen fibrils. In thick sections the characteristic wavy course of the fibrils, as described by Apathy, Bethe, and others, can be seen. No heavy connective-tissue sheath is found surrounding the smaller nerve trunks. There is, however, a thin connective-tissue sheath about some of the smaller nerves, which, in the main nerve trunks, becomes quite noticeable, and forms a decided capsular sheath around the ganglion.

In the central nervous system the conditions are more difficult to make out. The structure seen could be best explained by the elementary network of Apathy or the anastomosis of Bethe. The sheath appears to be lost, and the interior of the ganglion (neuropile of authors) seems to be made up of fibers of different sizes, crossing and recrossing each other. These fibers are frequently seen to branch or divide dichotomously, but no clear cases of anastomoses have been made out. This is difficult because of the widely different courses taken by fibrils in the ganglion. Intermingled with the nerve fibrils and almost indistinguishable from them are the so-called neuroglia fibers. Neuroglia nuclei are scattered through the ganglion as well as through the nerve trunks. Whether the fibrils just described are homologous with the primitive fibrils of Apathy and Bethe, the author is not prepared to say without further research. Such, however, seems to be the case.

One interesting fact with regard to a comparison of my results with those of Nansen, who worked on the nerve tube of Ascidians (see Nansen, Pls. XXI, XXII), might be given here. It was observed that the nerve trunks, as well as the central ganglion fiber mass, when treated with chromic mixtures such as Nansen used, gave results much like those exhibited in his plates. The shrinkage caused by the chromic acid gave the nervous tissue the appearance of a number of tubes. If, however, these so-called tubes were followed to the ganglion

cells it was found that not the hollow portion of the tube but its wall seemed to make up the axis cylinder. In specimens killed in Von Rath, Hermann, Flemming, or sublimate, fluids which gave much less distortion and shrinkage, the clear area between the so-called walls of the nerve tubes is seen to be filled with fine fibrils. These fibrils in chromic material are evidently shrunken and lie close to the wall of the "tube." Indeed some specimens show the fibrils lying against the wall of the "tube."

Centrosome and Sphere in the Tunicate Ganglion Cell.

In nerve cells containing excentric, flattened, or invaginated nuclei, as well as in many cells not showing this nuclear disturbance, were found the structures which I have taken homologous with the centrosome and sphere of Von Lenhosseck,

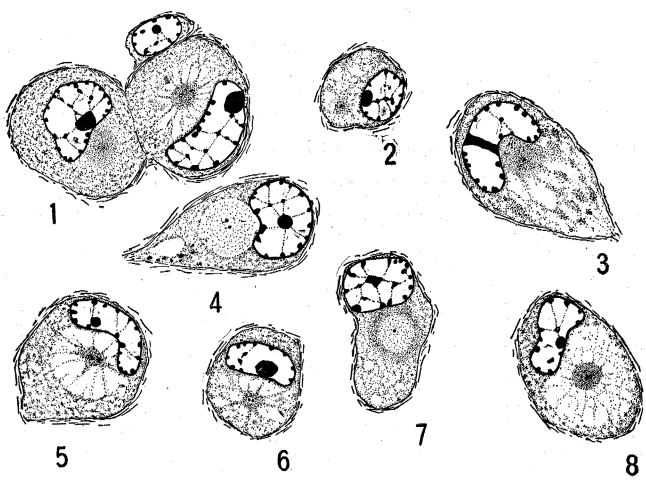

Fig. 5. — Centrosome and sphere in ganglion cells (*Cynthia*). 1, Von Rath; 2, 3, 5, 6, 8, Flemming; 4, Perenyi; 7, chrom-oxalic. Iron-haematoxylin. Camera drawings. $\frac{1}{12}$ × oc. 6 (Zeiss).

Dehler, Lewis, McClure, and others. In most general terms the structure can be spoken of as consisting of three parts. Beginning from the outside and going inward we have first: an outer coarsely granular zone — the granular zone of McClure and Lewis. The area of this zone varied greatly (see

Fig. 5). In some specimens it was as much as three-fourths of the cell diameter; in others it was much smaller and less pronounced. It is made up of the coarse granules of the peripheral part of the cell-body. Next is found a clearly staining area, homogeneous or finely granular, which always contains one, often several, black deep-staining granules, the centrosome or central bodies of authors. This clear area corresponds to the sphere of Von Lenhosseck or the disc of McClure. Such an area may be of considerable size and contain visible radiations which extend out into the surrounding cytoplasm (Miss Lewis), or may be reduced so as to be almost or completely wanting (see Fig. 5). The central bodies are of variable number. One large granule is frequently found; perhaps two is the most constant number. This last statement seems especially true for young cells.

The above-described type of centrosome is often met with, but there are many modifications. In some of the cells of a ganglion may be found a centrosome with well-developed astral rays, presenting the appearance found in leucocytes. In other cells of the same ganglion (see Fig. 5) may be found a centrosome with the typical archoplasmic condensation around it. In still other cells the centrosome may have little or no condensation of cytoplasm about it, and may exist as a deep-staining granule in the cell. Again, such a centrosome as last mentioned may be made up of several granules which seem to be more or less solidly welded together. All these forms or states of centrosomic activity may be present in one or the same section (see Fig. 5). This figure shows that the centrosome structure is not a fixed one, such as Von Lenhosseck pictures, but extremely variable in form, more so than Miss Lewis figures. It seems evident from this that the centrosome, as a dynamic center, is of varying importance in different cells. This is further shown by the differing amount of condensation in other cells, as well as the manner in which the nucleus is indented. In these cells, all described being from adult specimens of varying age, we see represented various-sized cells. There seems to be no restriction as to size, although the centrosome is much easier to prove in the larger cells.

It would be difficult to give the proportion of cells found which contained centrosomes, as in many specimens after staining no such structure can be proved. The nucleus, although excentric, appears ovoid or circular, and no concentric arrangement of the cytoplasm can be observed. In such cells, however, the centrosome may exist as a granule, although no such state has been proved.

Several very young animals from two to three mm. long were killed shortly after metamorphosis. In such specimens the ganglion cells, although nearly as large as in the adult, contained nuclei much larger in proportion than those contained in the adult cells. The nuclei were much richer in chromatic material than in the adult. The most striking feature noticed

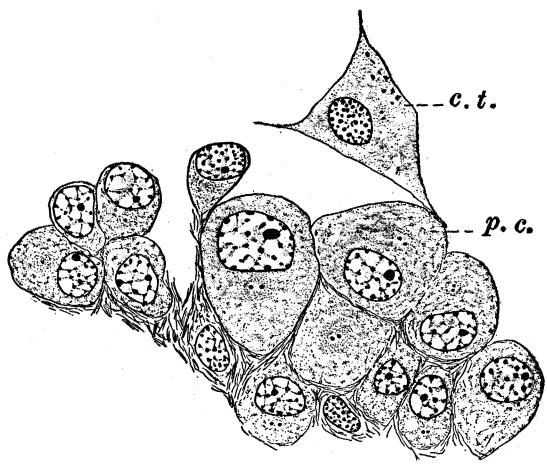

FIG. 6. — Cross-section of brain (*Cynthia*) shortly after metamorphosis, showing centrosomes in ganglion cells. *p.c.*, large peripheral cells; *c.t.*, connective-tissue cells. Von Rath. Iron-haematoxylin. Camera drawing. $\frac{1}{12}$ × oc. 6 (Zeiss).

was the fact that a very large proportion of the cells was found to contain centrosomes, although in most cases the sphere and radiations were lacking. It cannot be positively stated that all ganglion cells at this stage contain centrosomes, but certainly a very large proportion do, as can be seen by a glance at Fig. 6. The centrosome in these cells is usually double, *i.e.*, two central bodies are found. There seems to be no common axial relation between the direction of the two bodies and the long

axis of the cell. In general a very small clear area may be said to surround the central bodies, but it is small compared with the same area in cells of older specimens. A very slight condensation is frequently found, but it is also slight as compared with older cells. Rarely, if ever, are astral rays found. In some few cases a decided granular condensation of the archoplasmic type is found. But in the majority of cases the centrosome in the young cell differs from the same structure in the old cell, by existing without protoplasmic rays extending from the central body, frequently without any condensation of cytoplasm about it, and often exists as one or a pair of deeply staining granules, situated in the central part of the cell-body. More than all, it differs in the amount of mechanical influence exerted on the cell structures. In the cells of the young *Cynthia*, where the nucleus is proportionately so much larger than in older cells, we would expect a most decided invagination and excentricity. But such is rarely the case. Exceptionally do we find a nucleus with a decided invagination, and flattened nuclei are rare. The nucleus is, however, always excentric. It is round or ovoid in shape, rarely flattened or pushed into an outpocketing of the cell-body, as is observed in older specimens. These facts can only be explained on the supposition that the centrosome does not exert any decided mechanical influence on the cell protoplasm, as is seen by the absence of a disc, sphere, or radiations. Indeed in many small cells the centrosome seems pushed to one side by the larger nucleus.

The centrosome does not seem to have any fixed position in the cell-body. It was most frequently found between the nucleus and the cell process near the center of the cell. It was also frequently found to lie between the nucleus and that part of the cell most distant from the cell process. It might even lie laterally between the nucleus and the cell membrane. Such positions appeared to be normal.

The question of the function of the centrosome is of extreme interest, although with our present data it is very far from being solved. Von Lenhosseck has little to say with regard to its probable function, and, with Dehler, seems to consider it a centrosome once actively functioning in division but left over

in the resting cell. Miss Lewis believes the structure homologous with the centrosome and sphere in dividing cells.[1] McClure thinks the central bodies and disc found in *Helix* are morphologically equivalent to the centrosomes and sphere commonly found in other cells. The papers of Buhler and Schaffer I have not seen.

It is evident that, at least in certain stages of its existence, the centrosome has a mechanical influence in the cell protoplasm. As we have seen in young specimens of *Cynthia*, a condensation of cytoplasm about the central bodies, with the accompanying indentation of the nucleus, is lacking. But in such cells as contained the centrosome, with its sphere and radiations or condensation, a marked mechanical force seems to be excited. This was shown by the excentric position of the nucleus, the flattening or invagination of the nuclear membrane on the side toward the sphere, the condensation and concentric arrangement of the cytoplasm about the central body, and the frequently found radiations extending toward the periphery. However, no instances of mitotic division were found. Binucleated nerve cells were seen, and cases where nuclei were so flattened and distorted by the invagination as to be nearly divided into two parts, but in no case anything like mitosis was found. Recent investigation seems to point to the fact that nerve cells, although they may remain for a long time in a so-called embryonic state, *i.e.*, as neuroblasts functionally inactive, never divide as adult cells. No cases of mitotic division of nerve cells have been yet placed on record, so far as known to the author. It would seem, then, that another explanation must be found for the presence of the centrosome in the ganglion cell.

More recently is advanced the theory that the centrosome may be left over in the cell from its embryonic state to be called forth into activity by seasonal conditions. Such a view was hinted at by Von Lenhosseck in his reference to Meves's paper

[1] In Miss Lewis's second paper, "Studies on the Central and Peripheral Nervous Systems of Two Polychaete Annelids," *Proc. Amer. Acad. Arts and Sciences*, vol. xxxiii, No. 14, 1898 (which came too late to be inserted in the bibliographical list), she pictures ganglion cells containing two spheres; but she concludes that the ganglion cells, after an early embryonic period, never divide.

on the centrosome in the tendon of Achilles of the frog. Meves thinks the centrosome a permanent cell organ which in old cells may not be functionally active. Von Lenhosseck points out that Meves's observations were made on winter frogs, and thinks that perhaps with the renewal of life activities the cell might divide again. The author has not yet concluded any experiments in this direction, as his material was limited to a killing period of three months, June to September. Such experiments in *Cynthia* would be difficult, because probably no actual hibernation period takes place, although the life activities may be reduced in winter. One interesting fact might be noted, however; if the central ganglia of several specimens, killed in the same fixing fluids and exposed to same conditions of technique, are sectioned, stained in iron-haematoxylin, and examined, it is found that some specimens show nearly all the cells of the ganglia to contain centrosomes and spheres, with accompanying indentation of the nuclei, while other specimens show few if any cells in this condition, and the centrosome, if present, not surrounded with a sphere or radiations. In other words, at a given time of the year (summer), certain ganglion cells in some animals are observed to contain centrosomes, while corresponding cells in other animals seem to lack this structure. It is important to note that the age of the specimens cannot be taken into consideration, and this may be an important factor.

It seems to the writer that the centrosome in the ganglion cells must have a meaning other than cell division. Might it not serve the same function as it appears to have served in certain cells possessed of protoplasmic movement, such as leucocytes, giant cells of bone marrow, embryonic blood corpuscles, pigment cells, etc.? In leucocytes it has been shown by Flemming ('91) and Von Rath ('95) that the centrosome is apparently not engaged in mitotic division, as a sphere and central body are found existing in cells in which the nuclei are divided, seemingly by amtosis. In the liver cells of an isopod (*Porcellio*) the attractive sphere is not concerned in the division of the cell. Other like cases have been observed. In such cells as the pigment cell the centrosome appears to be a dynamic center, causing contraction or expansion (chromatophore of cephalopods).

It is well known that, in early life at least, the ganglion cell is migratory. Such a cell is shown in Fig. 3. It has wandered out from the ganglion (shown in next section), and is probably on its way to the periphery. This cell is observed to contain two centrosomes. It is worthy of note that in the mammalia the only ganglion cells in which centrosomes are found (so far as known) are those of the spinal and sympathetic ganglia. The cells of the spinal ganglia have probably migrated from the central system; the cells of the sympathetic are proved to have migrated from such a source. In the spinal cord cells bordering the central canal migrate out into the cord. These cells are the neuroblasts. The above facts seem to prove that the ganglion cell in certain stages of its existence has the power of locomotion. Might not the centrosome preside over the locomotor power of the cell — in the ganglion cell as well as in the leucocytes?

The theories of Englemann and Cajal, in regard to the movement and growth of the ultimate ends of the cell process, are interesting from this standpoint. According to these authors, the cell processes are capable of growth and may branch, forming more and more complex endings. These endings may at one time be in connection with one set of cells, at another time with another set, thus giving many new pathways between different cell groups at different times. Here again is the idea of movement of parts of the cell. Could the centrosome influence such movement? Would such movement, if it existed, be homologous or analogous to the movement in pigment cells? Such questions cannot yet be answered.

This suggestion in regard to the possible function of the centrosome in the ganglion cell must not be taken for fact or theory. It is only suggestion. Much more work must be done and many more facts gathered before such a view could be taken for a theory. But it is hoped that at some future time the problem may be successfully attacked and solved.

SUMMARY.

The principal points treated in this paper are as follows :

I. The demonstration of the fibrillar nature of the nerve process as opposed to the "nerve tube" of Nansen. Positive proof of the elementary network of Apathy and Bethe is lacking. Such a view could, however, best explain the structure of the neuropile of the ganglion (brain) of *Cynthia*.

II. The presence in the nerve cell of ganglion bodies of different size, which color strongly with methylen blue and which are of different chemical structure from the groundwork of the cell. These bodies are undoubtedly homologous with the chromophilous substance in many invertebrates (Pflüge, McClure) as well as in vertebrates. The ground substance of the cell appears granulo-fibrillar. Frequently fibrils may be proved in the cell, especially near the process, and in the periphery of the cell. A cone of entrance was frequently found.

III. The existence of the centrosome and sphere in the ganglion cell. This structure was found in adult as well as in young specimens killed a few days after metamorphosis. In the young cell the structure more frequently existed without radiations, and with little or no cytoplasmic condensation about the central body or bodies. The centrosome was proved in a greater proportion of cells in young specimens. In older specimens the centrosome and sphere, although not limited to cells of certain size, was proved in fewer cells proportionately. When found it exhibited all possible variations from the central body with little or no cytoplasmic condensation to a decided sphere with cytoplasmic radiations extending almost to the periphery of the cell. In the latter case the nucleus was deeply invaginated and pushed far to one side of the cell, while in cells with little or no radiation and small sphere the nucleus was often ovoid, or only slightly flattened.

It is hoped in a later paper to give a more complete account of the fibrillar structure of the nerve trunks, and to throw some light, if possible, on the function of the centrosome in the ganglion cell.

HULL ZOÖLOGICAL LABORATORY,
May 15, 1898.

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